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Effectiveness of Systems Engineering (SE) Tailored for the Science & Technology (S&T) Environment: Improvement of USAF Airdrop Accuracy

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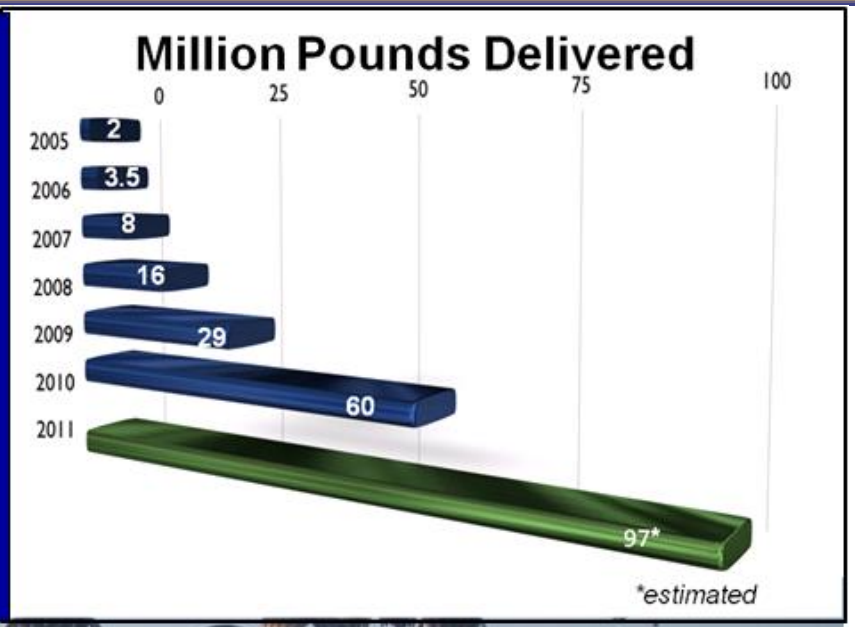
Background

- USAF Aerial Delivery Operations Increasing Dramatically
- Drove Need to Improve Accuracy for
  - Critical Resupply
  - Humanitarian Aid
- AMC Requested AFRL Investigate Technology Solutions
  - Aid Development of Systems to Achieve AMC Need
  - Many Complexities Drove Need for Systems Engineering
  - S&T SE Process Drove FY12 AFRL Technology Investment
    - Multiple Technology Projects Planned in 2011

Air Force Need

"AMC has a need to provide aerial delivery of a broad range of assets with superb accuracy from extended airdrop offset distances and higher altitudes. Single pass capability solutions should be considered…" Gen Raymond Johns, Commander AMC, 2011



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Presentation Outline

- Entrance Criteria for PAD
- Integrated Product Team (IPT)
- S&T SE Process Steps
- Initial Project S&T Development Strategy
- User Understanding of Desirements
- Products from S&T SE Process
- Categories of Candidate Technology Options
- Techniques to Score Solution Options
- Methods to Combine Options into Alternatives
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- Findings from Application of S&T SE Process
- Critical Roles Played by S&T SE in Pre Milestone A

Entrance Criteria for Precision Airdrop

- Documented/Prioritized MAJCOM Capability Gap
- Commissioned Via AF S&T Governance Structure
- Linked to Service Core Function Master Plan
- Initial S&T Development Strategy Initiated
- Between a Leading Development Planning Concept and a Prototype
- Assigned to Lead Center for Transition
- MAJCOM Transition Manager Identified
- Defined S&T Baseline/Exit Criteria
- S&T Activity Ideally Completed During Current FYDP

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Integrated Product Team

- The Precision Airdrop (PAD) IPT
  - Air Force Research Laboratory (AFRL)
  - Air Mobility Command (AMC)
  - US Army NATICK
  - Electronic Systems Center (ESC)
  - Aeronautical Systems Center (ASC)
  - US Air Force Academy (USAFA)

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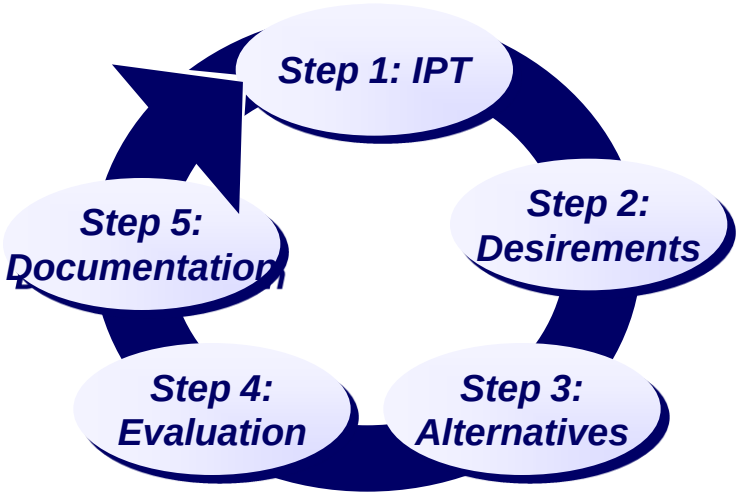
S&T SE Process



- Develop Desirements and Metrics
  - Solicit Input from All Stakeholders
  - Define Measurands, Desirability Functions, and Relative Importance
  - Repeat as Knowledge Advances
- Generate Technology Alternatives and Conceptual Designs
- Perform Value Analysis to Evaluate Alternatives
  - Evaluate Alternatives against Desirements
  - Compute Desirability and Risk for Each Concept
  - Explore Trade Space
  - Generate or Refine Alternative Approaches
  - Select Most Promising Approach
- Deliver Results: Recommend Alternatives

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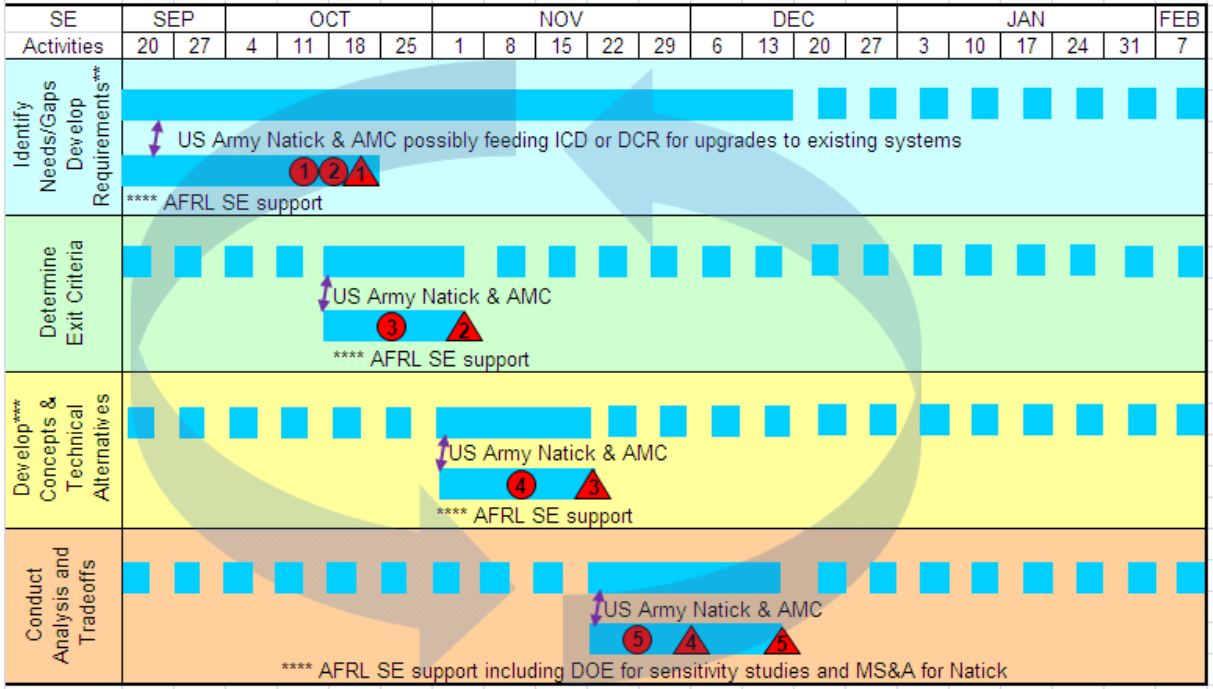
Initial Schedule

Schedule* for Systems Engineering (SE) Support to an AFRL Future Capability Concept Precision Airdrop (PAD) Program
Version 2.5 as of 12 Oct 10



Legend: ▲ ● Complete ▲ ● Open

Notes:

*	This schedule will be maintained as a living document. SE Activities need to be iterative across *'swim lanes,' not serial.*
**	Possible System-of-Systems approach, building requirements at that level, and then backing off to focus on PAD
***	AFRL Team will look beyond a single S&T solution; will address long-term ramifications regarding cost and schedule
****	AFRL Team will start small, engage with SMEs, visibility for Directorate Chief Engineers, possibly include RB, RX, RY…

○ Meetings supported by SynGenics and MacAulay-Brown *(Meetings 2–5 are 2–3 days.)*

1. AFRL Core Team *(incl. 3–4 SMEs)* at Scott AFB with AMC and US Army to discuss an AFRL FCC for PAD and to agree on means of providing a "single voice" to AFRL for both services.
2. AFRL Core Team at WPAFB with AMC and Army Natick for 2 days of SynGenics-facilitated PAD *Requirements Development*
3. AFRL Core Team at Scott AFB with AMC and Army Natick for SynGenics-facilitated development of PAD *Exit Criteria*
4. AFRL Core Team at Scott AFB with AMC and Army Natick for SynGenics-facilitated *Development of Concepts/Alternatives*
5. AFRL Core Team at Scott AFB with AMC and Army Natick for SynGenics-facilitated *Analysis and Tradeoffs*

△ Products

1. Joint AMC / US Army PAD Requirements
2. Joint AMC / US Army PAD Exit Criteria
3. Full Set of Concepts/Alternatives (tech and operational)
4. Analysis and Tradeoffs vs AMC/Army PAD Desirements
5. AFRL Flagship Capability Concept (FCC) Baseline for PAD

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Precision Airdrop (PAD) Focus Areas

- ***Precision*** **was the Original Focus of the PAD Project**
- **AMC's Desire was for AFRL to Address Urgent Needs in**
  - **Critical Resupply**
  - **Humanitarian Airdrop**
- **These Urgent Needs Shaped the Definition of "Precision"**
  - **Precision was Viewed only as Impact Point Accuracy**
- **The PAD Project now Addresses Precision as**
  - **Single Pass**
  - **Dispersion Predictability and Tailorability**
  - **Situational Awareness of Bundles**
  - **Impact Point Accuracy**
  - **Predictability in the Event of Malfunction**

6 Desirements

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Eight S&T SE Process Deliverables

- **Documented Criteria: Includes "Exit Criteria"**
- **Alternatives: Potential Solution Concepts Captured, Defined, and Assessed Against all Criteria**
- **Analysis: a Mathematically Based Evaluation of Alternatives, Including Quantified Predictions of**
  - **Response Values Related to Criteria**
  - **Desirability, Uncertainty, and Risk**
- **Sensitivity Analysis: Reveals Highly Leveraged Parameters Through Exploitation of their Acceptable Ranges**
- **Relationships:**
  - **Between Factors and Responses**
  - **Among Desirements**
- **Understanding: the Process Demands that all Desirements be Satisfied and the Solution "Trade Space" be Understood**
- **Worksheets and Scorecards: Framework for Presentation of Results & for Revisiting Them when New Information Emerges**
- **Consensus**

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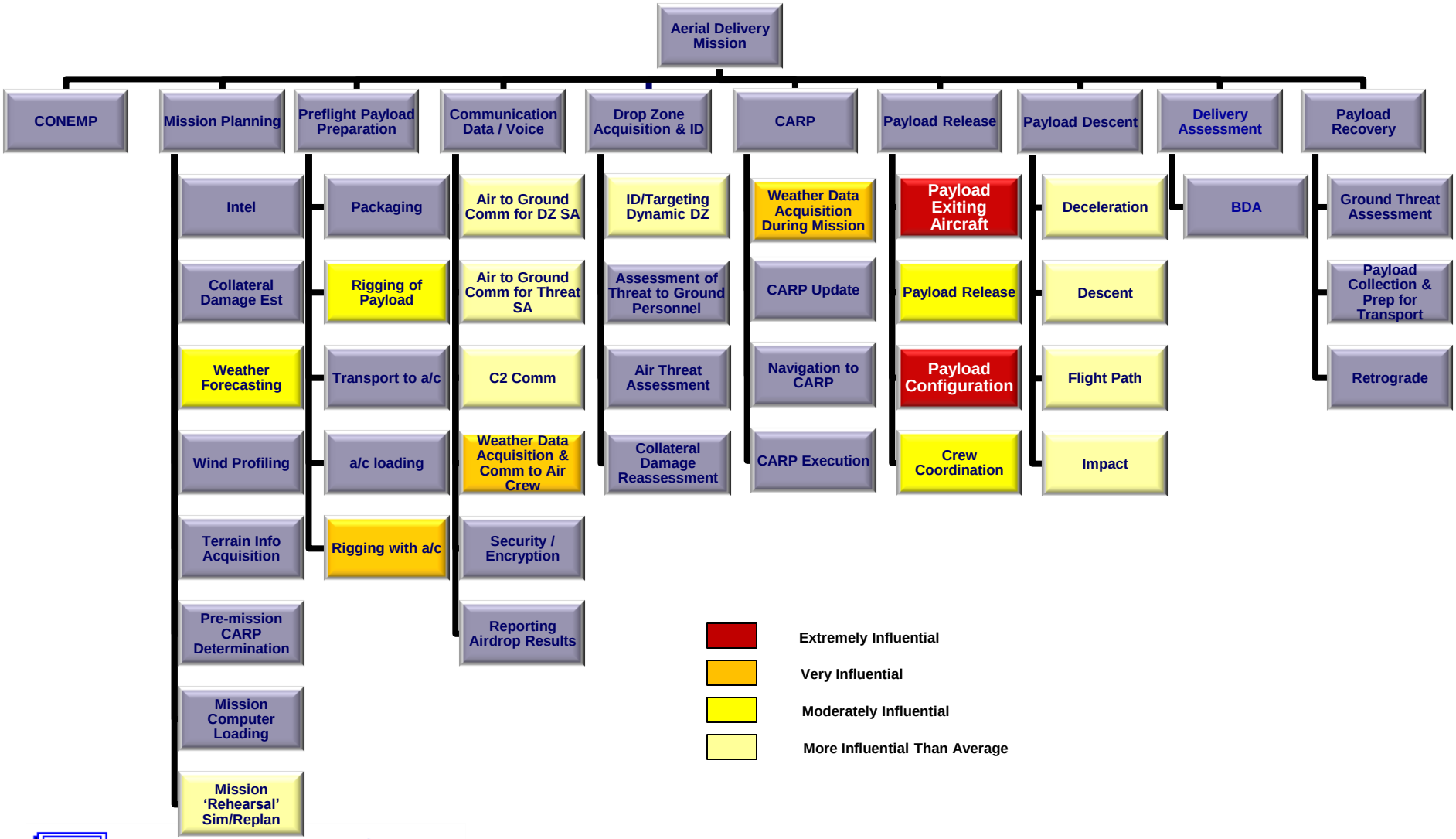
Functional Work Breakdown Structure (FBS)



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Categories of Candidate Technology Options
For FBS Elements

- Payload/Exit Improvements — *Current Focus*
- Communication/Display Improvements
- Weather Data Acquisition Improvements
- Human Factors Mitigation
- UAV Integration
- Additional Studies

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Scoring of Options
Initial Assessment

Des #	Desirement Name	Units	Current		I-Skid		I-SkidAdv		I-Dun		I-DunAdv		I-Release		Active Shaping		ForceEx		Air Bags	
			Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst	Expecte	Wor/Bst
Category: A. Performance																				
P01	Impact Point Accuracy	meters	400	800	325	725	300	675	400	800	400	800	250	650	175	575	175	575	400	800
P02	Predictability of Dispersion Pattern	meters	200	400	162.5	362.5	150	337.5	200	400	200	400	125	325	87.5	287.5	87.5	287.5	200	400
P03	Accuracy of CARP Execution	yards	100	200	100	200	100	200	100	200	100	200	100	200	100	200	100	200	100	200
P04	Predictability in the Event of Malfunction	Confidence	90		92		92		90		90		92		95		95		90	
P05	Platform Agnostic	Scale: 1–5	1		5		5		5		5		1		1		1		5	
P06	Likelihood of Avoiding Collateral Damage	Probability	90		92		94		92		94		92		95		95		90	
P07	Communication Capability	Scale: 1–5	2	1	2												2	1	2	1
P08	Agility / Flexibility	Minutes	20		20												20		20	
P09c	Number of Passes	Count	1	2	1												1	2	1	2
P09h	Load Deliverable in a Single Pass	%	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
P10	Survivability of the Load	Confidence	90		90		90		93		95		90		95		90		97	
P11	Bundle-Awareness Capability	Scale: 1–5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P13	Mass Capability (Max)	lb	2200	2200	10000	15000	10000	15000	10000	15000	10000	15000	10000	15000	10000	15000	10000	15000	2200	2200

Scoring of 36 options against 34 desirements completed 13 Dec

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Combining Options into Alternatives

- **Generated Alternatives as All Combinations of Options in Accordance with Rules Established:**
  - **Every Alternative Had at Least One Option from Each Type**
  - **No More than Two Weather Options Were Allowed**

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Scoring Alternatives

- Scored Each Alternative against Desirements Using Worst, Best, or Multiplicative Rules Applied to Scores of Options Present
- Analyzed Customer Desirability of 19,530 Alternatives thus Generated
- Inspected Top 5,000 Alternatives (Type of Pareto Analysis)
- Generated Scorecards for Customer Desirability and Risk for Top 12 Alternatives
- Identified Alternatives that Offer Greatest Chances for PAD Improvements

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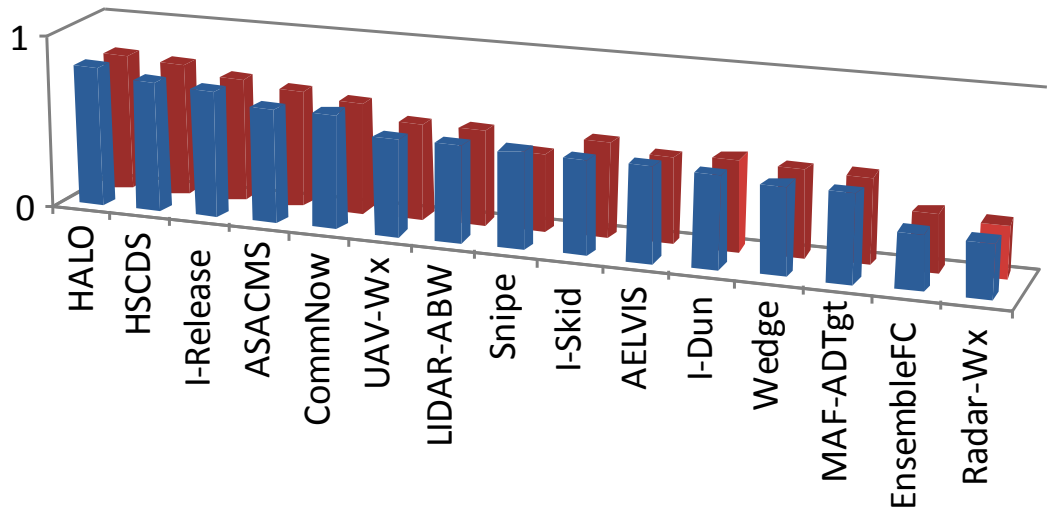
Findings

- No Single Option Solved the Entire Problem
  - Hence the Need to Evaluate Alternative System Solutions
- No 0–3-yr Option Addressed
  - P14, Minimum Mass Delivery Capability
  - HF5, Rigging Workload
  - HF6, Rigging Training Required
- Doing Less Is Superior for Human Factors Desirability
  - Can Only Hurt Security
- Risk Analysis Is Suspect Because of Scoring Concerns

Options in Best Alternatives

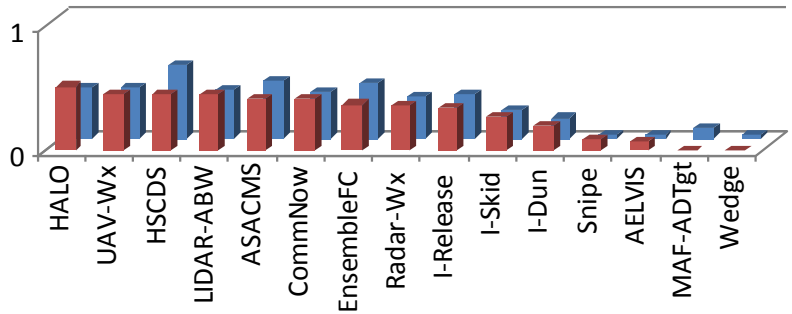


Frequency of Occurrence of 0–3-yr Options in Top 5,000 Alternatives for $D_{Performance}$ or $D_{Overall}$

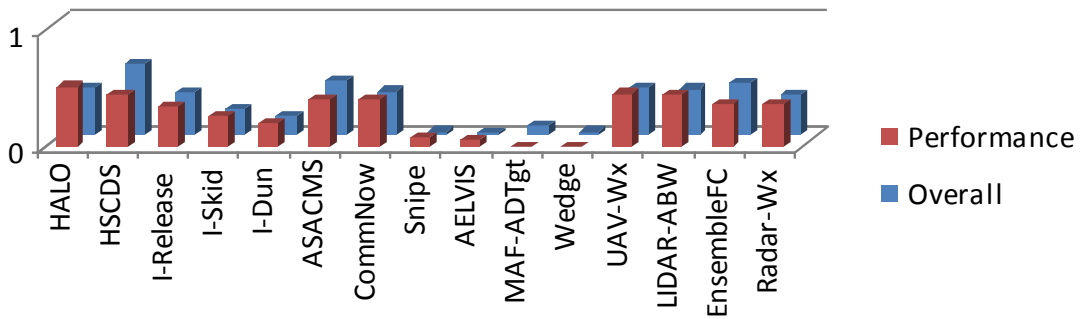
Option	Type	Perf	Overall
HALO	1	91.6%	82.1%
Snipe	2	72.2%	33.2%
HSCDS	1	67.1%	71.9%
ASACMS	2	66.7%	70.7%
CommNow	2	66.6%	56.6%
AELVIS	2	65.8%	51.4%
I-Dun	1	59.0%	59.5%
I-Release	1	57.5%	57.5%
I-Skid	1	55.1%	51.1%
Wedge	2	50.0%	50.1%
MAF-ADTgt	2	49.9%	46.2%
UAV-Wx	3	43.1%	39.1%
LIDAR-ABW	3	43.0%	38.7%
EnsembleFC	3	39.8%	48.4%
Radar-Wx	3	39.2%	34.0%

Cost Sensitivity?

- **Contribution to "Goodness" When More Options Are Allowed within an Alternative**



- **Contribution When Only 3 or 4 Are Permitted**



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Way Forward (as of 29 Sep 11)

- Completed Assessment of Alternatives Scorecard
  - Identified Alternatives Offering Greatest Chances for Improvement to PAD
  - Briefed Results to the AFRL/AMC Team, Initiating the IPT Planning Phase (Exit/Comm/Weather/Human Focus)
- Alternative IPTs Refine Alternatives and Define Tech Path Forward (28 Jan)
- Interim Review with AFRL/CC (28 Feb)
- Integrated Baseline Review Completed (27 Sep)
- IPT for Each Focus Area is in Place to Commence Execution of FY12-16 Plan

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Summary

- The Systems Engineering (SE) Approach is an "*Eye-Opening*" Experience…Making Us Think Outside What We Already Knew
- A Cross-AF/Service/TD Team was Formed
  - Met ≥ Weekly to Capture/Refine Desirements and Generate/Evaluate Solutions
- The AFRL-Employed S&T SE Process is Generating New Thinking to Solve a Critical AF Need

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Observations by Leaders

- **AMC, by Col Peet, AMC/A8X, in a Message to Dr. Erbschloe, AMC/ST:**

"...we think all this work is great, and will inform future efforts also. So, definitely keep this scoring methodology. We do find great value in it."

- **AFRL, by PAD Project Lead:**
  - **The Process Broadened Scope of Analysis to Include**
    - **Traditionally Army-Owned Pieces of the Problem**
    - **Very Near-Term Technology Options**
  - **A Detailed FBS of the Airdrop Problem Revealed Issues that Would Have Been Overlooked had a SE-Based Approach not been Employed.**

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